

## SEXUAL DIFFERENCES IN TIMING OF AMERICAN KESTREL MIGRATION AT HAWK MOUNTAIN SANCTUARY, PA

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**ABSTRACT.**—Bimodal migration patterns occur in many raptor species but have not been conclusively documented for American Kestrels (*Falco sparverius*) along their Appalachian migration route. Kestrels migrating past Hawk Mountain Sanctuary, Pennsylvania had a bimodal fall migration pattern when data were averaged over a 26-year period (1963–1988). Peaks at Hawk Mountain centered around 11 September and 2 October. Proportion of males increased slowly over the course of the fall migration; the median date for female kestrels preceded males' by 11 days. Both males and females showed bimodal migration patterns. Potential factors resulting in such patterns include timing of molt, location of summering grounds, and seasonal weather patterns.

Migration patterns of numerous North American raptors exhibit a bimodal distribution. Juvenile Sharp-shinned Hawks (*Accipiter striatus*), Cooper's Hawks (*A. cooperii*), Northern Goshawks (*A. gentilis*), and Northern Harriers (*Circus cyaneus*) precede conspecific adults in migration (Bildstein et al. 1984; Clark 1985a; Mueller and Berger 1967, 1968; Mueller et al. 1981) and female Merlins (*Falco columbarius*) migrate earlier than males (Clark 1985b).

Female American Kestrels precede males during fall migration at one site in the eastern Great Lakes region (Haugh 1972; Duncan 1985). An analysis of banding data for kestrels during fall migration east of 100° latitude suggests that a two-wave fall migration pattern may extend throughout the eastern United States (Smallwood 1988). However, no observational data document this pattern along specific migration routes other than the Great Lakes flyway. Although kestrels migrating past the Great Lakes and Appalachian Mountains represent 2 different populations with distinct winter ranges (Roest 1957; Clark 1975; Duncan 1985), we cannot assume migration patterns are similar.

Banding data alone cannot substantiate migration patterns, since data may have a bias toward birds which are more susceptible to capture (McClure 1984:323–324). Timing of banding, type of lure used, and behavioral differences between sexes (especially if timing of capture susceptibility varies between sexes) could all contribute to an apparent bimodal pattern that does not accurately reflect true migration timing. Patterns seen in banding data and replicated with observational data become more believable.

In this study, we first examine kestrel migration data collected at Hawk Mountain Sanctuary, Penn-

sylvania to see whether a bimodal pattern for kestrels exists along Appalachian migration routes. We follow this with analysis of counts of known sex kestrels seen at Hawk Mountain, to see if a sexual difference in timing of migration exists. Documentation of such a pattern along the Appalachian migration route would support the hypothesis that separation of sexes must occur on breeding grounds or early in migration (Smallwood 1988).

### METHODS

Hawk Mountain Sanctuary, Pennsylvania (40°44'N, 75°50'W), is located on the Kittatinny Ridge, the southernmost line of the northern Appalachians. Geographic and topographic features concentrate tens of thousands of migrating raptors along this ridge each fall (Brett 1986). Migration counts have been taken at Hawk Mountain Sanctuary North Lookout (elevation 464 m) since establishment in 1934. Observers record number and species of all migrating raptors seen from the lookout almost daily during the fall.

We summed the number of kestrels sighted during each week of fall migration from daily counts made during fall migrations of 1963–1988. We then calculated a weekly average for the 10 most active weeks of kestrel migration, 25 August through 2 November. We omitted observations made before 1963 because of numerous gaps in the data.

Heavy precipitation usually halted migration and resulted in a daily count of zero. We included zero-count days in the calculation of weekly means with the assumption that overall weekly migration volume was not affected; kestrels halted by poor weather conditions probably resumed migration when weather conditions improved. Weekly means were used to alleviate short-term fluctuations in migration volume caused by the passage of weather fronts.

Before 1 September, some zero-count days were caused by the absence of an observer at the lookout. Although data for the first week of the migration period may slightly underestimate migration volume, we feel that the difference was minor and did not affect the overall migration

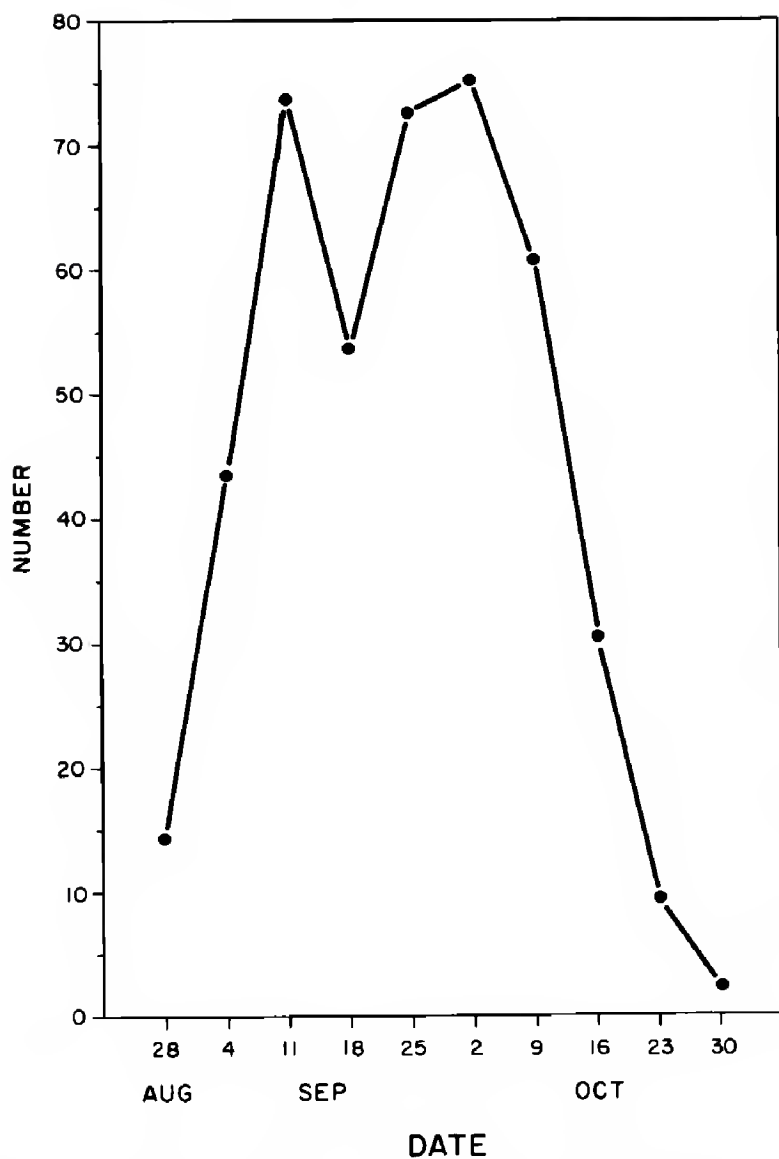


Figure 1. Mean number of American Kestrels seen weekly during fall migration at Hawk Mountain Sanctuary, 1963-1988. Mid-week dates are given.

pattern observed. We included a test of kurtosis (Sokal and Rohlf 1981) to verify non-normality of the data.

In 1979 observers at Hawk Mountain began to record sex of kestrels passing the lookout. Sightings were tabulated by sex and date of observation. We searched for a difference in the timing of migration by each sex using ranked dates of observation in a Wilcoxon two-sample test (Sokal and Rohlf 1981). To test for a difference in relative numbers of males and females during 2 periods of the migration period, we used a G-test (Sokal and Rohlf 1981) for all sexed birds. G-test analysis was performed twice. First, we used 18 September as the date to divide the migration period; 18 September represented a trough in the bimodal pattern of kestrel migration. Second, we used the median date for all sexed kestrels (22 September) as a dividing date.

We compared weekly totals for counts of each sex to

the overall migration pattern, again limited to the ten heaviest weeks of kestrel migration. Sampling effort for sexed kestrels varied over the course of the migration period (<6%–>22% of passing kestrels). We adjusted raw numbers of kestrels of each sex observed each week by multiplication with a correction factor for sampling effort, as follows:

$$\frac{\text{number of kestrels sexed during the week}}{\text{total number of kestrels seen during the week}}$$

#### RESULTS

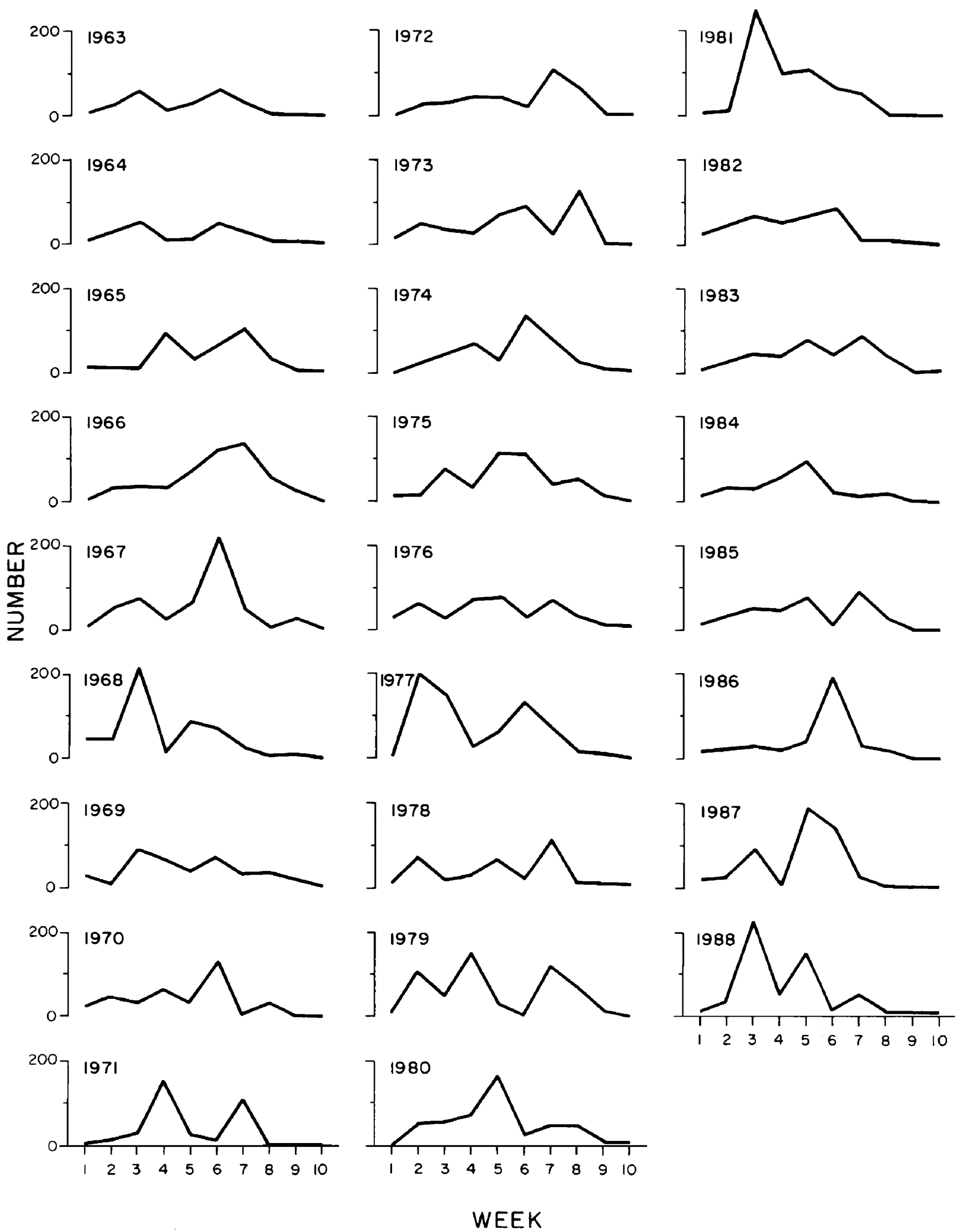
Mean weekly number of kestrels during fall migration at Hawk Mountain peaked on 11 September and 2 October (Fig. 1) when averaged over the 26-year period (1963-1988), representing an extreme platykurtosis ( $g_2 = -0.796$ ;  $t_s = -17.304$ ,  $P < 0.001$ ). A bimodal pattern existed in many individual years at Hawk Mountain and was especially clear in 1963-1965, 1968, 1971, 1974, 1977, 1985 and 1987 (Fig. 2).

Relative number of males increased gradually during the 10 heaviest weeks of the migration period ( $N = 793$ ), although both sexes showed a bimodal distribution in timing of migration (Fig. 3). Because of low counts for the final 2 weeks of the period, data for 20 October-2 November were lumped into a single data point for presentation. When all sexed birds were tabulated ( $N = 837$ ), the G-test revealed a significant difference in the proportions of males and females around the trough date ( $G = 35.47$ ,  $P < 0.001$ ). On or before 18 September, females outnumbered males (males = 161, females = 201); after 18 September, males outnumbered females by almost 2:1 (males = 309, females = 166). Conclusions did not differ when the median date of all sexed birds (22 September) was used as the dividing date ( $G = 32.58$ ,  $P < 0.001$ ). Median date of sighting for female kestrels, 14 September, differed significantly from that of males, 25 September ( $t_s = 6.547$ ,  $P < 0.001$ ).

#### DISCUSSION

American Kestrels migrating past Hawk Mountain Sanctuary (1963-1988) had a bimodal migration pattern (Fig. 1). The proportion of male kestrels increased as the fall progressed, indicating a differential timing of migration by each sex. Relative val-

Figure 2. Total number of American Kestrels seen during each week of fall migration at Hawk Mountain Sanctuary, 1963-1988. Week numbers correspond to mid-week dates presented in Figure 1.



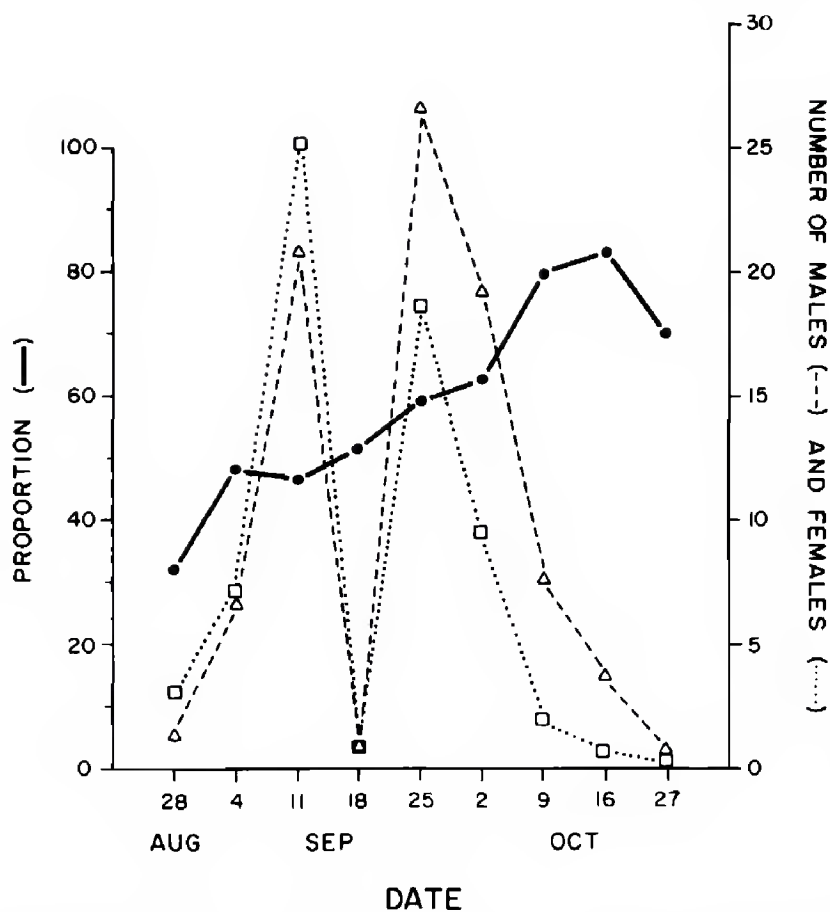


Figure 3. Proportion of male American Kestrels (●) observed at Hawk Mountain Sanctuary, relative to all known sex kestrels recorded during each week (1979–1988). Adjusted numbers (see text) of male (△) and female (□) kestrels seen each week of the migration period (1979–1988).

ues of these proportions over time should be unaffected by the apparent skew toward males in the sexed kestrels. The skew toward males does not appear to represent a bias toward males in sampling for sex, as the pattern for all sex and age classes (Fig. 1) shows a corresponding larger second peak. Our data indicate that a sexual difference in migration timing may be a general pattern common to all kestrels in eastern North America (Duncan 1985; Smallwood 1988). The data may also confirm that different arrival times of sexes to wintering grounds is not an artifact of a local separation of birds on or near wintering grounds, but rather a difference in time of departure from breeding grounds (Smallwood 1988).

Sexual difference in migration timing may be related to different roles during the breeding season. Smallwood (1988) suggested that female kestrels are able to initiate migration before males because females complete their molt earlier. Males provide most of the food for their mate and developing young during the breeding season and molt later than females (Willoughby and Cade 1964; Smallwood 1988).

Female kestrels are slightly larger than males (Reynolds 1972; Snyder and Wiley 1976), but no sexual dominance is obvious. On wintering grounds in Florida, both territorial male and female kestrels are able to exclude late-arriving members of either sex (Smallwood 1988). Therefore, females may benefit by migrating as early as their molt permits in order to establish territories in favorable habitats before males arrive on wintering grounds (Smallwood 1988). Sexual variation in migration timing could explain differential habitat use which has been reported for kestrels (Koplin 1973; Mills 1976; Stinson et al. 1981; Bohall-Wood and Collopy 1986; Smallwood 1987, 1988).

Differential migration timing by sex may also be related to a difference in distance traveled. Some investigators have reported that male kestrels winter further north than females (Roest 1957; Willoughby and Cade 1964; Johnson and Enderson 1972; Stinson et al. 1981). Males compete for breeding territories in the spring (Newton 1979), and may be at an advantage to winter on or near breeding territories. Selection may favor males with greater ability to survive in the rigorous habitats of more northern wintering grounds (Mills 1976), and these males may delay their migration relative to females.

Sexual difference in migration timing among kestrels passing Hawk Mountain Sanctuary does not preclude the possibility that juveniles precede adults in migration and may also contribute to the observed bimodal pattern. Juveniles of many raptor species migrate before adults (Mueller and Berger 1967, 1968; Mueller et al. 1981; Bildstein et al. 1984). Analyses of banding data (Smallwood 1988) suggest that juvenile kestrels and adult females precede adult males in migration. We expect the effect of juveniles on the patterns observed at Hawk Mountain to be minimal since the migrations of juvenile raptors are concentrated along the Atlantic coast (Clark 1985b).

The striking trough seen in migration counts for both sexes of kestrels passing Hawk Mountain (Fig. 3) may be related to a number of factors. The molt timing hypothesis (Smallwood 1988) described above suggests that non-breeding males, in addition to females, could benefit from an early migration, and the first peak of males (Fig. 3) could represent non-breeding males that did not have their molt delayed by food provisioning. Confirmation would require matching breeding status of migrants to the timing of their migration but would not explain the second peak for females.

An alternative explanation might be that the 2



peaks for each sex represent individuals from separate populations. Verification would require knowledge of summering grounds of kestrels passing Hawk Mountain. This explanation alone does not seem adequate, because the data accordingly suggest that sex ratios of each population are different.

The trough could also indicate an overriding annual weather pattern which consistently limits kestrel migration during the third week of September. However, variation in annual patterns (Fig. 2) suggests that such a mechanism did not operate every year. A more detailed examination of weather effects at Hawk Mountain is needed. None of our explanations excludes any other and observed patterns probably result from a complex interaction of numerous factors.

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